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Environment, Safety, and Health

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Part 17: Explosives/Firearms

17.1 Explosives

(Formerly H&SM C24)

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17.1

Explosives*

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Explosives

1.0 Introduction

Serious consequences can occur if explosives are handled improperly; therefore, no operation involving explosives may be conducted unless a safety plan [i.e., Facility Safety Plan (FSP) or Operational Safety Plan (OSP)] has been prepared and approved, and the work has been authorized by an Integration Work Sheet (IWS). This document provides guidance for implementing the requirements in DOE M 440.1-1 (*DOE Explosives Safety Manual*) as well as work controls necessary for ensuring the safety of operations involving explosives. Together, the *DOE Explosives Safety Manual* and this document describe the LLNL Explosives Safety Program.

Activities, operations, and processes that are not in compliance with the DOE manual's guidance (denoted by "should" or "may"), but are considered to be safe and necessary, may be approved by LLNL through written approval by the facility associate director (AD) in the form of a waiver for an alternate solution. Waivers shall be issued only for the minimum time necessary and are to be updated every 3 years for ongoing activities. Appendix A prescribes the format and content for waivers.

The requirements in this document apply to LLNL operations involving explosives at the LLNL Livermore site and Site 300, the Nevada Test Site (NTS), and offsite locations where LLNL has primary safety responsibilities.

2.0 Hazards of Explosives

The major hazards from explosives are personal injury and property damage caused by heat, blast, noise, fumes, and flying debris or projectiles from unintentional or inadequately controlled ignition or explosion of such materials. Injuries, ranging from minor to fatal, could include trauma, lacerations, eye injury, hearing impairment, and burns. Property damage could range from minor to major.

Energetic materials are especially vulnerable to elevated temperature, with possible consequences ranging from mild decomposition to vigorous deflagration or detonation. Energetic materials can also be initiated by mechanical work through friction, impact, or electricity (e.g., current flow, spark, electrostatic discharge, or electromagnetic radiation). Other stimuli (e.g., focused laser light or chemical incompatibility) can have consequences ranging from mild decomposition to detonation.

Explosives may be toxic, with exposure pathways being inhalation of dust or vapor, ingestion, or skin contact. Most explosives are not highly toxic, but improper handling

can result in systemic poisoning, usually affecting the bone marrow (i.e., the blood cell-producing system) and the liver. Some explosives are vasodilators, which cause headaches, low blood pressure, chest pains, and possible heart attacks. Some explosives may irritate the skin.

Some detonation or combustion products from explosives are toxic. Such products can be respiratory and skin irritants and lead to systemic effects following short-term exposure to high levels. Soot from detonated explosives is not mutagenic; however, soot from burned gun propellants may be mutagenic and is therefore treated as a mutagen.

3.0 Controls

3.1 Safety Plans

FSPs and OSPs for explosives operations apply requirements from the LLNL *Environment, Safety, and Health (ES&H) Manual* and the *DOE Explosives Safety Manual.* Each explosives facility conducts its normal operations within the scope of a safety plan specifically written for the operations of a particular building, group of facilities with like operations and hazards, or other work area. No operation involving explosives may be conducted unless an FSP or OSP has been prepared and approved and the work has been authorized with an IWS (except as noted in Section 3.11). In addition to the general requirements described in this document, FSPs or OSPs involving explosives shall address the following:

- The quantity–distance assessment for the facility or work area.
- A description of the United Nations Organization (UNO) hazard class / division and compatibility group of the explosives authorized.
- Personnel limits for the work area (i.e., limits on the number of operators and casuals).
- Operating explosives limits.
- Fire and emergency actions or response procedures that may be relevant.
- Protective clothing and equipment.
- Warning signals.
- Special testing of equipment needed before operations (such as stray voltage and calibration checks).
- Removal of all explosives not needed for the operation.
- Inspection and cleanup procedures after a test or detonation.

The supervisor of the operation, although responsible for preparing the safety plan, can obtain advice and assistance from the ES&H Team supporting the area. The Responsible Individual should contact the ES&H Team as soon as possible to ensure that all requirements are included during the planning phase.

All safety plans involving explosives (i.e., OSPs and FSPs) are required to be reviewed annually by the Responsible Individual and ES&H Team explosives safety engineers to determine if any new safety controls are necessary. If the plan no longer completely addresses the operation, or if new safety considerations (e.g., compatibility, toxicity, and ignition sources) have been identified, the plan shall be revised.

3.2 Working with Explosives

3.2.1 General Requirements

The safety plan for an explosives operation shall describe the hazards of the explosives work area and the applicable safety controls. The following requirements apply to all explosives work areas:

- Use the minimum amount of explosives necessary for the operation. The posted weight limit for an area is a maximum and shall not be exceeded.
- Limit, and keep to a minimum, the number of personnel involved in an explosives operation.
- Ensure that all personnel who handle explosives are trained and qualified as outlined in Section 3.22.
- Post applicable safety warning signs (e.g., fire symbol, explosives weight limits, and personnel limits) near all entryways to the explosives area.
- Repair and service all equipment and apparatus as outlined by the maintenance requirements for the facility.
- Remove all explosives from the work area and put them either in a magazine or an approved safe file, vault, or cubicle during maintenance work that requires open flames or welding.
- Use suitable eye protection when working or visiting eye-hazard areas, particularly when electroexplosive devices are being handled. All explosives operations shall be evaluated for eye hazards.
- Control electrical instruments and test meters used with explosives systems as outlined in Document 17.4, "Electrical Instruments for Use with Explosives Systems," in the *ES&H Manual.*

- Decontaminate and inspect explosives equipment before transferring it to a nonexplosives area. Equipment should be cleaned prior to being stored in the explosives area.
- Regularly collect and remove waste explosives and material contaminated with explosives from the facility. The method of waste collection and frequency shall be stated in the controlling safety plan.
- Keep explosives work areas clean and reasonably neat. Clean up explosives spills as they occur.
- Handle explosives carefully. Do not throw, drop, tumble, or drag explosives. Such rough handling creates shock and friction, which can result in fire or detonation.
- Package explosives to be moved or stored in an approved container with adequate padding to prevent movement within the container.
- Prohibit smoking in explosives areas, except in designated locations. Smoking is not permitted within 25 ft of explosives. Fire, flame, or spark-producing devices are not allowed in explosives areas except when approved by a Hazardous Work Permit (see Section 3.18).

3.2.2 Personal Protective Equipment

Each operation shall be analyzed to determine when personnel working with explosives and toxic materials shall wear ES&H Team-approved coveralls or laboratory coats to prevent contact with the materials and to prevent contaminating personal apparel. Flame-retardant coveralls may be required for certain explosives operations when there is the possibility of a flash fire. Such coveralls shall not have cuffs or metallic fasteners.

Cotton (or other antistatic material) outer and undergarments, including socks, shall be worn when static electricity would create a hazard. Safety plans shall include protective clothing and equipment requirements.

3.2.3 Explosives Hazard Classification System

LLNL uses the UNO hazard classification system for classifying explosive materials and explosive components. The UNO system is recognized internationally and is used universally by the Department of Defense (DoD), other Department of Energy (DOE) contractors, and the Department of Transportation (DOT). The procedure for the hazard classification of explosives is contained in Appendix C.

The UNO system consists of nine classes of dangerous materials, with explosives designated as Class 1. The explosives hazard class is further subdivided into six divisions, which are used for segregating ammunition and explosives on the basis of

similarity of characteristics, properties, and accident effects potential. The six hazard class / divisions are described in Table 1. For explosives, the term "hazard class" should be used when referring to hazard class and division.

Table 1. Explosives hazard class/divisions.

Hazard class/division	Hazard description
1.1	**Mass explosion**
1.2	**Nonmass explosion, fragment-producing**
1.3	**Mass fire, minor blast or fragment**
1.4	**Moderate fire, no blast or fragment**
1.5	**Explosive substance, very insensitive (with a mass explosion hazard)**
1.6	**Explosive article, extremely insensitive**

Under the UNO system, there are 13 storage compatibility groupings, which further categorize Class 1 explosives by their form or composition, ease of ignition, and sensitivity to detonation. Appendix B contains a listing of the more common explosives that can be found at LLNL. Each Storage Compatibility Group (SCG) in use at LLNL is described below with examples:

- **SCG A**—Bulk-initiating explosives that have the necessary sensitivity to friction, heat, or percussion (shock) to make them suitable for use as initiating elements in an explosive train. At the Laboratory, for the purpose of procedural controls, a distinction is made between primary initiating explosives and nonprimary initiating explosives. Examples of primary initiating explosives are lead azide, lead styphnate, mercury fulminate, and tetracene. Examples of nonprimary initiating explosives are dry forms of cyclotetramethylene tetranitramine (HMX), cyclotrimethylene trinitramine (RDX), and pentaerythritol tetranitrate (PETN).
- **SCG B**—Detonators and similar initiating devices that do not contain two or more independent safety features. This group also consists of items that contain initiating explosives designed to initiate or continue the functioning of an explosives train. Examples are blasting caps, small arms primers, fuzes, and detonators of all types.

  Note: Exploding bridgewire (EBW) and slapper detonators are excluded from this group for onsite operations.
- **SCG C**—Bulk propellants, propelling charges, and devices containing propellant with or without their own means of initiation. Upon initiation, these items will deflagrate, explode, or detonate. Examples are single-,

double-, and triple-base propellants; composite propellants; rocket motors (solid propellant); and ammunition with inert projectiles.

- **SCG D**—High explosives (HE) and devices containing HE without their own means of initiation and without a propelling charge. This group includes explosives and ammunition that can be expected to explode or detonate when any given item or component thereof is initiated. This group does not include devices containing initiating explosives with independent safety features. Examples are wet HMX, plastic-bonded explosives (explosives formulated with a desensitizing plastic binder), trinitrotoluene (TNT), and black powder.

  Note: For storage and onsite operations only, Group D includes EBW and slapper detonators, as well as assemblies, candle pads, and mirror pads with either EBW or slapper detonators attached.

- **SCG E**—Explosives devices that lack their own means of initiation but contain or have a propelling charge (other than one containing a flammable or hypergolic liquid). Examples are artillery ammunition, rockets, and guided missiles.

- **SCG F**—Explosives devices that have their own means of initiation, with or without propelling charge. Examples are grenades, sounding devices, and similar items with an in-line explosive train in the initiator.

- **SCG G**—Pyrotechnic materials and devices containing pyrotechnic materials. Examples are devices that, when functioning, result in illumination, smoke, or an incendiary, lachrymatory, or sound effect.

- **SCG H**—Ammunition containing both explosives and white phosphorus (WP) or other pyrophoric material. Ammunition in this group contains fillers that are spontaneously flammable when exposed to the atmosphere. Examples are WP, plasticized white phosphorus (PWP), or other ammunition containing pyrophoric material.

- **SCG J**—Ammunition containing both explosives and flammable liquids or gels. Ammunition in this group contains flammable liquids or gels other than those that are spontaneously flammable when exposed to water or the atmosphere. Examples are liquid- or gel-filled incendiary ammunition, fuel–air explosive (FAE) devices, flammable liquid-fueled missiles, and torpedoes.

- **SCG K**—Ammunition containing both explosives and toxic chemical agents. Ammunition in this group contains chemicals specifically designed for incapacitating effects more severe than lachrymation. Examples are artillery or mortar ammunition (fuzed or unfuzed), grenades, and rockets or bombs filled with a lethal or incapacitating chemical agent.

- **SCG L**—Explosives or ammunition not included in other SC/HC groups. This group includes explosives or ammunition with characteristics that do not permit storage with other similar or dissimilar materials. Examples are damaged or suspect explosives devices or containers, explosives that have undergone severe testing, fuel–air explosive devices, and water-activated devices. Also included are experimental explosives, explosives of temporary interest, newly synthesized compounds, new mixtures, and salvaged explosives, unless established as being compatible with the original materials. Types of explosives in this group presenting similar hazards may be stored together.
- **SCG N**—Hazard Division 1.6 ammunition containing only extremely insensitive detonating substances (IEDS). Examples are bombs and warheads. If dissimilar Group N munitions, such as MK 82 and MK 84 bombs, are mixed together and have not been tested to assure nonpropagation, the mixed munitions are considered to be Hazard Division 1.2, Storage and Compatibility Group D, for purposes of transportation and storage.
- **SCG S**—Explosives, explosives devices, or ammunition presenting no significant hazard. Explosives ammunition, so designated or packed that, when in storage, all hazardous explosives effects are confined and self-contained within the item or package. Materials in this group are such that an incident that destroys all items in a single pack will not be communicated to other packs. Examples are thermal batteries, cable cutters, explosive actuators, and other ammunition items packaged to meet the criteria of this group.

Note: Some explosives change classification and compatibility when removed from their approved DOT shipping container.

3.3 Identification and Labeling

Containers of explosives shall be clearly identified by the use of an LLNL-explosives identification label on the exterior of the container. The minimum information required includes the name of the explosive material, hazard class, division, storage compatibility group, net explosives weight, identification number, processing review date, and stability review date if applicable (see Section 3.4). Contact ES&H Team explosives safety engineers for information on how to acquire standard labels.

The properly completed explosives identification label shall be placed on the container when the explosives are packaged on completion of processing and shall remain in place during storage. When explosives are removed from a primary container, a secondary method shall be used to maintain the identity of the explosives.

Immediate action shall be taken to secure and identify explosives samples, parts, pieces, or containers that are not identified. Explosives that cannot be identified shall be stored as SCG L explosives.

3.4 Storing Explosives

This section describes the requirements for storing explosives.

3.4.1 General Requirements

The following requirements shall be adhered to when storing explosives:

- Store explosives and explosive devices in an approved and locked service or storage magazine (e.g., safe file, vault, cubicle, room, or separate facility).
- Post applicable safety warning signs (e.g., the fire symbol, the EXPLOSIVES WEIGHT LIMIT sign, and the PERSONNEL LIMIT sign) near all entryways to the explosives storage area.
- Check to assure that each container of explosives is properly labeled to identify the contents.
- Segregate explosives for storage on the basis of compatibility and lot number.
- Stacks of explosives shall be arranged so that air freely circulates to all parts of the stack.
- Pallets or appropriate dunnage shall be used to ensure that containers are not stacked directly on the magazine floor.
- Inspect storage locations and explosives containers at least once a year to ensure continued safe storage.
- Maintain a running inventory for each magazine.
- Inventory service magazines every three months and storage magazines annually.
- Have available two 2A / 10BC fire extinguishers or equivalent fire suppression equipment whenever work is being performed in or around a magazine.

3.4.2 Storage Compatibility

Each explosive material or explosive device shall be assigned to an appropriate hazard class, division, and storage compatibility group before being placed in storage. If compatible, different types of explosives may be stored together in the same storage magazine or storage area. The storage compatibility mixing chart in Table 2 is used for

determining compatibility and group mixing. The possibility of chemical interaction shall always be considered when placing any explosive in common storage with another storage compatibility group. Explosives in substandard or damaged packaging, in a suspect condition, partially reacted, or with characteristics that increase the risk of an accidental explosion in storage are not compatible with other explosives. Such explosives shall be assigned to SCG L and stored separately from other explosives.

Table 2. Storage compatibility mixing chart.

Groups	A	B	C	D	E	F	G	H	J	K	L	N	S
A	x[a]	z[b]	c										
B	z	x	z	z	z	z	z					x	x
C		z	x	x	x	z	z					x	x
D		z	x	x	x	z	z					x	x
E		z	x	x	x	z	z					x	x
F		z	z	z	z	x	z					z	x
G		z	z	z	z	z	x					z	x
H								x					x
J									x				x
K										z[d]			
L											e		
N		x	x	x	x	z	z					x	x
S		x	x	x	x	x	x	x	x			x	x

Notes:

a An "x" in a block of the above chart indicates that these groups may be combined in storage. Otherwise, mixing is either prohibited or restricted according to the following paragraphs.

b A "z" in a block of the above chart indicates that, when warranted by operational considerations or magazine nonavailability, and when safety is not sacrificed, these groups may be combined in storage.

c No mark in a block indicates that combined storage is not permitted.

d SCG K not only requires separate storage from other groups, but also may require separate storage within the group.

e SCG L compatibility types presenting similar hazards may be stored together but not mixed with other groups.

Exceptions to the storage compatibilities summarized in Table 2 include:

- Small quantities of explosives, i.e., up to 2 kg (4.4 lb) total, may be stored in the same cubicle if the cubicle walls are designed to prevent propagation. The material allowed in each cubicle shall be designated for one of the following categories: HE, propellants, detonators and actuators, or primary and static-sensitive explosives.

- Items from SC or handling control Groups B, C, D, E, F, G, and S may be combined in storage if the net explosive weight does not exceed 454.5 kg (1000 lb) and the items are in approved containers.
- Group L materials can only be stored together if their hazards are similar.

3.4.3 Storage Review

LLNL has established a system to identify explosives that may have deteriorated with time. This system consists of a stability review and process review.

Stability Review Date. If an explosive is known to degrade in a hazardous fashion during storage or contains stabilizers, a stability review date shall be assigned to define when the explosive shall be monitored. A stability review date shall also be assigned for energetic materials with inadequate data for determining long-term stability. Most LLNL explosives do not require stability review dates. Stability review intervals and dates are assigned according to the guidelines specified in Document 17.2, "LLNL Energetic Materials Stability Review Program," in the *ES&H Manual*. The controls for working with stabilized materials are also specified in that document.

Processing Review Date. A processing review date is assigned to each batch of explosives and delineates the time interval during which the explosive may be withdrawn for use (where energy is applied) without additional testing. No work involving energy input (e.g., heating, mixing, machining, or pressing) is to be done on an explosive that has exceeded its processing review date until the explosive has been retested and a new processing review date assigned. The Chemistry and Materials Science Energetic Materials Program Element (EMPE) staff assigns processing review intervals and dates upon request.

3.5 Design Criteria and Laboratory-scale Operations with Explosives

At LLNL, research and development activities in work areas that are limited to no more than 500 grams of explosives are designated as laboratory-scale operations. The *DOE Explosives Safety Manual*, Chapter II, Section 21 and Chapter VI, Section 6, and this section contain requirements for facility design criteria and laboratory-scale operations. Facilities designed to totally contain blast and fragment hazards do not require separation from other facilities or structures according to standard inhabited building blast and fragmentation distances.

Work with explosives entails a level of risk dependent on the amount and sensitivity of the explosive involved and the type of operation to be performed. Before a facility is designed, a careful study of those variables shall be conducted to determine the amount of protection to be given the operator. Design criteria requirements for explosives

facilities, including laboratories, may be found in the *DOE Explosives Safety Manual*, Chapter VI, Section 6.

The following guidelines apply to all laboratory operations:

- Design walls between adjoining rooms to withstand the effects (i.e., blast and fragments) of an accidental detonation. The wall shall be sufficient to protect any personnel not directly involved in the operation
- Whenever blasts could cause laboratory window breakage, use nonshattering material instead of glass.
- Provide unobstructed escape routes into less hazardous areas. The number of exits from each room shall meet the requirements of the *DOE Explosives Safety Manual*, Chapter II, Section 2.
- Provide floor surfaces free of cracks or other places where explosives contamination could accumulate. If liquid explosives are used, seal the floor to prevent absorption of the explosive. There should be no floor drains in the laboratory area.
- In rooms containing remote operations, equip all entrances with physical barricades.
- Wiring and equipment shall meet the requirements of the *DOE Explosives Safety Manual*, Chapter II, Section 8.

Each operation at facilities designated for blast and fragment confinement shall be reviewed to ensure that the explosives limits are within the laboratory or test area capability. Explosives limits and safe separation distances shall be adjusted as the capability to confine fragment and blast decreases.

Each proposed operation for the laboratory or test facility shall be reviewed to determine all potential hazards. Considerations shall include:

- Structural limitations of the facility.
- Remote control viewing and operating equipment, if required.
- Special safety precautions for personnel elsewhere in the building.
- Safe separation distances.
- Required deviations from other sections of this document.

Experimenters shall use no more explosives in their laboratories or test facilities than absolutely required for a given operation. Particularly hazardous laboratory or test facility operations involving new (or relatively unknown) explosives shall be done as a remote operation. Approved operational shields shall be used in such operations and in new or untested applications of explosives.

3.6 Heating Explosives

It is common practice to heat an explosive for drying, pressing, curing, or thermal testing; however, improper application of heat can cause an explosion. Whether an explosion occurs depends on many factors, the most important of which are the chemical properties of the explosive, mass of the explosive, and physical condition (e.g., geometry and whether the explosive is confined or unconfined) of the system.

The critical temperature of an explosive is the lowest temperature at which the explosive in a given configuration self-heats to explosion. The critical temperature in general is to be avoided but certainly is not the only danger during the heating process. Other dangers include thermal degradation with gas pressure buildup and deflagration. Therefore, before heating an explosive, the maximum safe temperature that can be used for that explosive configuration shall be known.

When heating explosives, use the mildest set of conditions that will accomplish the task safely and efficiently. The *DOE Explosives Safety Manual*, Chapter II, Sections 12 and 13, describes the hazards and precautions that shall be observed when heating explosives. Any operation or experiment that involves the heating or drying of an explosive shall have a peer-reviewed safety plan (i.e., FSP or OSP) or Peer Review for Explosives procedure (available from the Energetic Materials Program Element staff or ES&H Team explosives safety engineers), and work shall be authorized through an IWS.

3.7 Machining Explosives

Explosives machining is a forming operation that involves mechanical cutting of the explosive material, often along with harder inert materials. Such forming operations include turning, drilling holes, coring, and sawing. All explosives shall be machined remotely unless the explosive is listed below as approved for contact machining. Machining explosives without liquid coolant, including the ones listed below, or in combination with metal shall also be done remotely. During remote machining, the operator either shall be protected by a suitable operational shield or be in a control room that provides adequate protection from blast and fragments.

Any explosive material that is not approved for contact machining shall be machined remotely. Appendix C contains the testing and approval requirements to be met before an explosive can be designated as contact machinable. The following explosives are approved for contact machining:

- Amatol.
- Baratol.
- Boracitol.

- Explosive D.
- Octol (to 75% HMX).
- Pentolite (to 50% PETN).
- RDX/TNT compositions with no more than 75% RDX. These include Composition B, Composition B-3, and 75/25 cyclotol.
- Triaminotrinitrobenzene (TATB) and TATB compositions with an inert plastic binder.
- TNT.

3.8 Operations with Large Explosive Charges

As the weight of an explosive or explosives device increases, the accident risk from mishandling also increases because of the greater likelihood of ignition and the increased severity of the consequences. A large explosive charge is defined as the following:

- A bare Hazard Class/Division 1.1 explosive billet or part that weighs 25 kg (55 lb) or more.
- An explosive assembly, including fixturing or other attached hardware, that contains an exposed Hazard Class/Division 1.1 explosive and weighs 25 kg (55 lb) or more.
- An exposed explosive that is not completely enclosed by a physical covering that would provide significant protection in the event of a handling accident. Pin dome hydro assemblies consisting of the shot stand and case are examples of assemblies that are not vulnerable to impact on bare internal explosive materials and therefore are not defined as a large charge.

When any LLNL-directed operation involves a large Hazard Class/Division 1.1 explosive charge, the additional controls and reviews listed in these sections are required and shall be included in the safety plan.

Existing safety plans for handling explosives that do not provide the safety elements listed below shall be supplemented by an additional Peer Review for Explosives Assembly procedure or a peer-reviewed OSP (see Document 3.4, "Preparation of Work Procedures," in the *ES&H Manual*). As a minimum, such detailed written procedures shall address the following additional operational restrictions and precautions:

- Minimizing the possibility of dropping the explosive during handling.
- Preventing dangerous impact in the event of a handling accident.

- Limiting any adverse effects of the sensitivity and thermal stability properties of the explosive.
- Eliminating hazardous chemical reactions between the explosive and any materials it may contact.

The procedures shall comprehensively consider all safety aspects of fabrication, transportation, and handling during every operation with the large charge. Lifting of large explosive charges with a crane or hoist are considered critical lifts (see Document 15.3, "Crane and Hoist Safety," in the *ES &H Manual*). The supplemental procedure shall also be reviewed by a member of the LLNL Large Charge Committee, the Hazards Control explosives safety subject-matter expert (SME), and facility management for each facility involved before being submitted for approval.

Explosive materials that are classified and approved by the DOE Explosives Safety Committee as extremely insensitive detonating substance (Hazard Class / Division 1.5) or very insensitive detonating articles (Hazard Class / Division 1.6) are exempt from the requirements of this section (see details in the following section).

3.9 Low-Energy Initiators

The *DOE Explosives Safety Manual* defines low-energy electroexplosive devices (EEDs) as being all EEDs except exploding bridgewire (EBW) detonators and exploding foil (i.e., slapper) detonators. Low-energy EEDs contain energetic materials that require less peak power to give a detonation output than an exploding bridgewire (EBW) or slapper detonator, which are high-power devices typically requiring peak power levels of 10^5–10^6 watts. In the past, low-energy initiators (LEIs) were considered EEDs that could be initiated by 0.1 joules or less at peak power levels of a few watts. LEIs are now defined as all EEDs that are more electrically sensitive than either EBW or slapper detonators or which require less power for initiation. The term "LEI" is now used interchangeably with low-energy EED. The use of LEIs, as now defined, requires greater control to maintain a low level of risk.

LLNL prohibits the use of LEIs whenever high-energy EEDs can be used for the same purpose. If an LEI that is initiated by 0.1 joules or less needs to be used in a specific application, the experimenter shall supply information concerning the safety of the LEI to the ES&H Team explosives safety engineer responsible for the area, who forwards this information to the LEI Committee for review. Controls for handling and use of LEIs shall be specified in an approved safety plan (i.e., OSP or FSP) and authorized with an IWS.

For additional details concerning the control of LEIs, refer to Document 17.3, "Low Energy Initiator (LEI) Operations," in the *ES &H Manual.*

3.10 Extremely Insensitive Detonating Substances

Some mass-detonating explosives, known as extremely insensitive detonating substances (EIDS), are so insensitive that the probability of accidental initiation or transition from burning to detonation is negligible. This insensitivity to detonation permits the explosive to be handled and worked with somewhat less restrictive controls than are normal for a mass-detonating explosive. A safety plan for work with an EIDS having less-restrictive controls describes the EIDS-specific controls approved for its use. To be categorized as an EIDS, an explosive shall pass a series of qualification tests described in the DoD *Ammunition and Explosives Hazard Classification Procedures* (TB 700-2) and be approved by the DOE Explosives Safety Committee. EIDS were formerly known as insensitive high explosives (IHE).

3.11 Operations with 10 Milligrams or Less of Explosives

The major hazards of explosives, as described in Section 2.0, are not present with explosives in very small quantities. In areas where explosives are normally not allowed, operations involving nonprimary explosives with a mass of 10 mg or less or primary explosives with a mass of 1 mg or less may be performed as work authorization level (WAL) 2 work. WAL 2 work involving explosives requires a review by an explosives safety engineer and an approved IWS.

Activities involving nonprimary explosives with a mass of 10 mg less or primary explosives with a mass of 1 mg or less are exempt from the following requirements:

- Labeling requirements, other than material name and quantity.
- Electrical requirements.
- Storage requirements.
- Posting of fire symbol signs and placards.
- Quantity distance requirements.
- Personnel and explosives limits.
- OSP.
- Annual inventory.
- Formal explosives handler training.

Even in such cases, however, the following shall apply:

- The operation to include transport of the material shall be reviewed by an explosives safety engineer, and the recommended controls shall be implemented.

- The personnel involved shall receive a safety briefing by an explosives safety engineer on hazards and required controls.
- A log shall be maintained showing all samples received in the area, the amount of each sample, where the sample is stored, and its ultimate disposition.

If several explosive samples of 10 milligrams or less are present in one area, and the total inventory exceeds 10 mg, the samples shall be stored to prevent propagation between samples. Otherwise, the area shall be considered an explosives location, and all the requirements of this document shall apply.

3.12 Mock Explosives

The term "mock explosive" is interchangeable with the term "mock HE." During some tests, it is often convenient to use a material that cannot detonate but that possesses the compositional or physical properties of an explosive. A mock explosive is a nondetonatable material used to simulate one or more properties of a high explosive. Names and composition of commonly used mock explosives are listed in the *LLNL Explosives Handbook: Properties of Chemical Explosives and Explosive Simulants* and in Document 17.5, "Controlling Nuclear Explosive-Like Assemblies (NELAs) and their Mock Components," in the *ES &H Manual.* Hazards Control explosives safety personnel can provide additional information.

Within the DOE complex, mock explosives are colored pink (or mottled white and pink) to indicate that the material is an explosive simulant and not an explosive. Therefore, explosive formulations that are pink in color are not to be used at LLNL unless a safety plan specifies the measures to be taken to avoid confusing the pink explosive with mock explosive. Likewise, mock explosive formulations that are not pink in color are not to be used at LLNL unless there are adequate controls specifying the measures that are to be taken to avoid confusing the non-pink mock explosive with real explosives. As an additional aid to identification, mock explosive parts and containers containing a mock explosive shall be labeled "mock explosive" or "mock HE." The assigned name and identification number shall also be included on the label to facilitate composition verification.

- The lot of mock HE molding powder was adequately identified and certified by the manufacturer before receipt.
- A sample of the lot received was LLNL-recertified.
- The part can be accounted for historically.
- Control of the part has been maintained and documented.
- The part is not being assembled with fissile material.

A mock explosive:

- Cannot detonate but is not necessarily inert and should not be labeled as such.
- May be toxic or combustible.
- May possess other hazardous properties (e.g., Mock 90010, which has a high barium nitrate content, is an exothermic material).

Wear gloves when handling mock explosive powder. Consult with the ES&H Team for the appropriate type of gloves for an operation. Avoid breathing its dust or the vapors from heated material by using a respirator with a particulate cartridge or an adequate dust-collection system. Dispose of unclassified mock explosive parts through the Hazardous Waste Management Division, and give classified mock explosive parts to the Materials Management Section for disposal.

3.13 Adhesives, Fillers, and Coatings Used with Explosives

Adhesives, fillers, and coatings that come into direct contact with explosives shall be carefully selected to ensure they do not produce a hazardous reaction or degrade an explosive's performance. In addition, such materials should not react with the explosive in any way that produces a toxic byproduct. Properties, formulations, compatibilities, and handling precautions for the various adhesives, fillers, and coatings that may be used with explosives are described in Appendix E.

3.14 Procurement of Explosives

Explosives are normally ordered through the Procurement & Materiel Department. However, if other arrangements are made, a memo shall be sent by the requester to the Site 300 Controlled Materials Group (CMG) and the Hazards Control explosives safety SME to specify the explosive material requested, the quantity, and the supplier's name. Before ordering, CMG shall approve explosives that are to be stored in CMG facilities to ensure the material is acceptable and that storage space is available. Contact CMG at Site 300 for the correct shipping address and delivery instructions. Information copies of routine purchasing requisitions shall be sent by Procurement & Materiel to CMG and the Hazards Control explosives safety SME well before the material is shipped to Site 300 to ensure the material is acceptable and that there is available storage space.

All requisitions and any other documents needed for procuring explosives shall indicate the name of the explosive material and the fact that the material is an explosive. When ordering an explosive not previously used at LLNL, the requester shall obtain all necessary information about the explosive's composition, safe handling procedures, storage shelf life, storage stability information (if applicable), shipping information, and

a material safety data sheet from the manufacturer or supplier. The requester also shall obtain a processing review date and stability review date (if applicable) from the EMPE staff. The Explosives Safety Data form (Appendix D) is used to submit the safety data and is available from the EMP staff or ES&H Team explosives safety engineers.

Requests made to an outside organization for fabricating or handling a large explosive charge shall first be reviewed by the EMPE leader (or designee), who reviews the properties of the explosive and how they may affect the safety of the operation. The EMP staff may also suggest more suitable explosives that still meet design needs.

3.15 Shipping and Transporting Explosives

The Site 300 CMG of the Materials Management Section (of the Mechanical Engineering Department) is responsible for packaging, marking, and labeling explosives shipments leaving Site 300 and the LLNL Livermore site in a manner that complies with DOT, DOE, and LLNL standards. To ensure that the standards are observed, all explosives shipments to or from offsite locations shall be delivered in accordance with Document 21.2, "Onsite Hazardous Materials Packaging and Transportation Safety Manual," of the *ES&H Manual.* Controls for shipping and transporting explosives offsite are described in Document 21.4, "Shipping Explosives Offsite," in the *ES&H Manual.*

Personnel shall be properly trained and specifically authorized to transport explosives. Transportation at each site requires individual authorization. Only CMG and Site 300 Procurement & Materiel Department Materials Distribution Division personnel may transport explosives offsite. The Site 300 CMG can provide additional information.

3.16 Use of Electrical Equipment

Because explosives may be sensitive to heat, arcs, or sparks, electrical equipment and wiring shall be carefully designed and installed to limit the possibility of ignition during either normal or abnormal operating conditions. The *DOE Explosives Safety Manual* specifies minimum requirements for electrical installations and equipment in facilities containing explosives.

3.16.1 Portable Equipment

Portable equipment shall also conform to the appropriate classification when installed within explosives work areas. In some cases, equipment not otherwise acceptable for use in a hazardous location may be used if surrounded by an adequately purged and pressurized enclosure (see National Fire Code Standard NFPA-496). In other cases, equipment that is neither designed for hazardous locations nor capable of being purged may be used in the explosives work area when its presence does not increase risk and

its use is authorized by an electrical authorization tag (LL-3590) affixed to each piece of equipment or by an authorized equipment list [e.g., High Explosives Application Facility (HEAF) document 96-011, latest revision]. The tags are authorized by the facility point of contact (FPOC) and ES&H Team explosives safety engineers.

Some electrical equipment or operations are unacceptable for explosives work areas. In such cases, the explosives hazard shall be removed before the work is started or the equipment is installed. A Hazardous Work Permit (LL-1986) indicates concurrence of the facility point of contact and ES&H Team explosives safety engineers that the explosives hazard has been removed and the work in question can proceed.

3.16.2 Electrical Instruments and Test Meters Used on Explosives Systems

Many explosives systems used by LLNL are initiated by applying electrical energy to an initiation circuit within the system. Often, such circuits need to be tested for continuity and resistance with an electrical instrument. Some test instruments, however, can supply a large enough current to the meter probes (during either normal operation or a fault condition) to cause the explosives system being checked to initiate. To prevent this from happening, electrical instruments and test meters used with explosive systems shall be rigorously controlled and approved by the Explosives Instrument Committee (EIC). All users of electrical instruments in direct or indirect contact with explosives shall be familiar with LLNL's control system, as described in Document 17.4.

3.17 Explosives Waste Management

At LLNL, explosives waste and explosives-contaminated waste have been segregated into specified waste forms for the purposes of handling, storage, and disposal. The hazard classification system still applies to these waste forms (e.g., a Form 1 cased LX-14 explosives assembly would still be a Hazard Class / Division 1.1, SCG D explosive). The disposal method for explosives and explosives components shall be approved by the Explosives Safety Committee through peer review. The description of each explosive waste form and examples of each are given below.

Form 1—Waste explosives that because of configuration or composition are best treated by open detonation. Examples are explosive assemblies or devices that may detonate during open burning.

Form 2—Waste explosives that because of configuration or composition are best treated by open burning in the open burn pan. Examples are explosive parts and pieces generated during explosives formulation, processing, or testing or by removal from inventory.

Form 3—Waste explosives that because of configuration or composition are best treated by open burning in the thermal treatment unit (i.e., burn cage). Examples are wet machine fines generated during explosives processing, wet explosives-contaminated sludge from weirs and settling basins, and wet expendable filters from recycle systems.

Form 4—Waste material contaminated with energetic materials that are best treated by open burning in the thermal treatment unit (i.e., burn cage). Examples are paper, rags, plastic tubing, dry expendable filters from vacuum systems, and personal protective equipment used in explosives operations. The waste is assumed to retain explosives hazards and is therefore considered to be a reactive waste.

Nonreactive Debris—Debris slightly contaminated with energetic materials and similar to Form 4, with respect to the nonreactive component. The small quantities of contamination are so well dispersed that the waste does not retain explosive properties. The total quantity of contamination in the debris is controlled to trace amounts (i.e., approximately 1% or less by weight). Although no explosives safety controls apply to this category, controls for other hazardous materials may apply.

Explosives waste and explosives-contaminated waste are to be managed in accordance with the controlling safety plan for the explosives operation. Explosives wastes shall not be generated if no acceptable method for disposal exists or if transport on public highways is prohibited. The Hazardous Waste Management Division coordinates the proper storage, shipment, and treatment (if applicable) of such materials generated at the LLNL Livermore site or Site 300. The parties that generate explosives waste are responsible for coordinating with the Environmental Protection Department to assure available storage, proper shipment, or treatment, as applicable.

3.18 Hazardous Work Permits

A Hazardous Work Permit (Form LL-1986) is required for new construction, modification, maintenance, or repair work to be performed in any area designated as an explosives storage or handling area if the work involves any of the following:

- The shutdown of fire protection or detection systems in explosives facilities.
- Use of an open flame, for any purpose.
- Open-flame cutting or soldering.
- Welding (gas or electric) or grinding.
- Use of open fires for any purpose. (Controlled burning of grass requires special management and review and approval by explosives safety personnel but is exempt from this Hazardous Work Permit requirement.)

- Use of heat-producing (>228 °F / 109 °C) equipment or tools.
- Use of spark-producing or impact tools.
- Use of electric power tools.
- Use of powder-actuated tools (e.g., stud gun).
- Maintenance or repair work performed by subcontract workers.
- Disassembly of vacuum systems.
- Any penetration of the walls, roof, or floor of an explosives work room or explosives storage area.

ES&H Team explosives safety engineers shall review and approve the Hazardous Work Permit and inspect locations to ensure all explosives hazards have been removed and that appropriate safety precautions have been taken. ES&H Team explosives safety engineers can provide additional guidance for using and issuing the permits.

3.19 Emergencies

This section concerns emergencies involving explosives.

3.19.1 Fire

The most serious emergency in an explosives area is fire. Because most explosives are flammable and may detonate when exposed to excessive heat, take extreme care to eliminate sources of ignition from explosives areas.

In the event of a fire, immediately evacuate the area unless the fire can definitely be extinguished before it gets near any explosive. Do not attempt to extinguish a fire that directly involves an explosive. After the occupants evacuate to a safe area (see Document 22.3, "Response Plan for Fire in an Explosive Area," in the *ES &H Manual*), dial the emergency dispatcher (ext. 911) and give the necessary information. Take any additional actions specified in the safety plan for controlling the area.

Document 22.3 describes how emergency and facility personnel respond to a fire in an explosives area. It also contains information on hazard classifications, placarding facilities with fire division symbols, setback distances, and emergency withdrawal distances.

3.19.2 Reactive or Unstable Chemicals

On occasion, compounds in chemical supply rooms and other laboratory work areas have been found to contain constituents that have become reactive or unstable as a result of decomposition, dehydration, or peroxidation or are classified as explosives and

shall be handled accordingly. Chemicals that appear to have developed into an unstable state should not be handled or removed until appropriate guidance has been given by the ES&H Team industrial hygienist. Document 14.1, "Chemicals," in the *ES&H Manual* and *Standard for Storing and Using Peroxidizable Organic Chemicals* (see Section 6.3) provide additional information on peroxidizable chemicals. The ES&H Team explosives safety engineer can assist in providing information regarding the classification of questionable chemicals.

3.19.3 Lightning

Because of the hazards introduced into explosives operations by lightning, certain operations shall be stopped during the approach of lightning storms. A lightning detection system operates at the LLNL Livermore site (Building 191) and at Site 300.

Lightning warning procedures for explosives facilities are described in site-specific FSPs. Explosives operations that would be curtailed during lightning conditions shall be included in the safety plan for the operation.

3.20 Process Safety Management

Although no explosives manufacturing operations to which process safety management (PSM) requirements apply currently exist at LLNL, 29 CFR 1910.119 (known as the PSM Rule) shall be followed if it is determined that the rule does apply. Manufacture includes mixing, blending, extruding, synthesizing, assembling, disassembling, and other activities involved in the making of a chemical compound, mixture, or device that is intended to explode in any quantity. However, OSHA considers some activities (e.g., scale-up, research chemical formulations, and assembly of engineering research and development models) outside the scope of the explosives manufacturing process if conducted in a nonproduction research or test area or facility. [See the letter of interpretation issued by the Department of Labor (Miles 1998), listed in Section 6.3.]. Contact the ES&H Team for implementation guidance and identification of explosives operations to which the PSM Rule may apply.

3.21 Explosives-handling Equipment

This section concerns various types of explosives-handling equipment.

3.21.1 Carts and Hand Trucks

It is important for explosives handlers to use the proper cart or hand truck for moving explosive materials because inappropriate handling equipment can introduce additional hazards. All carts and hand trucks for explosives use shall be approved by an

ES&H Team explosives safety engineer. The following criteria apply to the design and use of carts or hand trucks:

- Carts or hand trucks used for bare explosives handling shall be provided with
  - A padded surface to support the explosives.
  - A lip, sides of sufficient height, or tie-down straps to prevent the explosives from sliding or rolling off this equipment.
- The equipment–load combination shall have a center of gravity low enough to prevent tipping in the event of a sudden stop caused by a wheel contacting an obstruction.
- New carts or hand trucks purchased after August 2000 shall be equipped with brakes.
- Carts or hand trucks containing explosives shall be positively secured (e.g., by setting the wheel brakes) when stationary. Carts without wheel brakes shall be chocked.
- Hand trucks shall be designed to be easily cleaned.
- Hand trucks should be numbered for ease of identification, maintenance, inspection, and recordkeeping.
- All hand trucks shall be inspected monthly by the facility supervisor. Damaged hand trucks shall be immediately removed from service.
- Hand trucks shall not be stored or left in walkways.
- Tea caddy-type carts may be used to move up to 2.2 kg (5 lb) of explosives between rooms, bays, or cells.
- Explosives shall be placed carefully on hand trucks. Explosives shall not be stacked on carts. Hand trucks should be used when explosives are moved from one processing bay to another within the same building.
- Ensure that the pathway is free of all obstructions and deformations that may jar the explosives during movement.

3.21.2 Vacuum-Lifting Fixtures

Prior to each use, vacuum-lifting fixtures and check valves shall be checked to ensure proper functioning. The operator shall perform the following:

1. Place the fixture on a surface similar to that of the part to be lifted.
2. Draw a vacuum on the fixture.

3. Disconnect the vacuum source and time the vacuum drop as shown on the gauge of the fixture. The initial reading on the gauge shall not be less than 508 mm (20 in.) of mercury, and the vacuum drop shall not exceed 50.8 mm (2 in.) in 1 minute after removal of the vacuum source.

When the vacuum-lifting fixture is attached to the part to be lifted, the operator shall check the device prior to each use to ensure the following:

- The line vacuum gauge and the fixture vacuum gauge give the same reading.
- All vacuum line connections to the fixture have been securely made.
- The rubber, neoprene, or plastic seal between the fixture and the part to be lifted is firmly and smoothly sealed.

3.21.3 Special Handling Fixtures

Special fixtures used to handle specific test units with explosives or explosive charges shall have a mechanical engineering safety note containing the design calculations and other supporting documents. Fixtures shall be tested and labeled with their maximum capacity and condition of use.

3.21.4 Fork Trucks

Explosives items that are too heavy or bulky for safe manual lifting may be moved over a short distance with an approved fork truck. Only qualified explosives handlers trained and authorized as fork truck operators shall be permitted to use fork trucks to transport explosives. Document 15.4, "Powered Industrial Truck Safety," in the *ES &H Manual* contains additional requirements for fork trucks used for explosives handling.

3.21.5 Cranes and Hoists

A safety plan and a Hazards Control review are required before mobile cranes are used for lifting bare or partially cased explosives. Personnel who use cranes or hoists to handle explosives but who are not qualified explosives handlers shall handle explosives only under the strict guidance of a qualified explosives handler. Document 15.3 contains more requirements for cranes and hoists used for explosives handling.

3.22 Training and Qualification of Explosives Users

Before being authorized to handle explosives, workers shall understand the hazards and safe practices associated with such work. The training that workers receive is determined by their current knowledge of explosives and the requirements of the job. Although the Hazards Control Department conducts formal training classes in

explosives safety, which are documented in Livermore Training Records and Information Network (LTRAIN), supervisors bear responsibility for providing on-the-job (OJT) training and ensuring that their personnel possess the knowledge and skills needed to perform the work safely.

3.22.1 Initial Qualification

An Explosives Handlers Training Qualification Record (Form RL-2999-9 or equivalent) is used to document performance of a work assignment, satisfactory completion of all safety-critical tasks, and approval of the training and qualification of explosives users. The Responsible Individual or work supervisor shall consult with ES&H Team explosives safety engineers to establish a training plan to include OJT requirements for all explosives handler candidates. An ES&H Team explosives safety engineer shall concur with the training plan, which shall be approved by the authorizing organization prior to the start of training. A copy of the initial Explosives Handlers Training Qualification Record shall be forwarded to an ES&H Team explosives safety engineer once the training has begun.

Upon completion of the specified training plan, the Responsible Individual or work supervisor, with ES&H Team explosives safety engineer concurrence, shall approve the individual as a qualified explosives handler. A copy of the completed Explosives Handlers Training Qualification Record shall be forwarded to an ES&H Team explosives safety engineer for updating the institutional explosives handler data base.

3.22.2 Medical Clearance and Surveillance

The Health Services Department provides medical clearance and medical surveillance for LLNL employees working with explosive materials. The purpose of the medical clearance program is to ensure that the employee is medically fit for this type of work activity. The purpose of the medical surveillance program is to monitor individuals that may be exposed to explosive materials either by direct skin contact or by respiratory exposure. Medical surveillance examinations are required on an exposure-adjusted basis.

Programmatic and work supervisors, in conjunction with the ES&H Team, are required to identify all workers who require medical surveillance and report this to the payroll supervisor. Payroll supervisors shall arrange for and obtain medical clearances for explosives handlers before allowing them to routinely handle bare explosives. Contact the Health Services Department for additional information.

3.22.3 Annual Review

Work supervisors shall annually review each explosives handler's qualifications and work assignment to ensure that the person is still capable of performing the operations indicated on the Explosives Handlers Training Qualification Record. In addition, the review includes a discussion of recent changes in pertinent procedures and other safety matters of concern to the supervisor or the worker. The review shall be recorded on an Explosives User's Qualification Review form (or a similar form), which can be obtained from Hazards Control explosives safety personnel. The form shall also record any new task assignments, any additional explosives safety training, and OJT training. A copy of the form shall be retained with the worker's Explosives Handlers Training Qualification Record and a copy forwarded to the applicable ES&H Team explosives safety engineer.

3.22.4 Suspension of Qualification

Supervisors shall not permit any worker to continue working with explosives if he or she is unable to perform the job safely because of physical injury, disease, mental disturbances, or a period of inactivity in work with explosives, for instance. When the worker is able to return to work with explosives, the work supervisor determines whether that person is still qualified. If not qualified, the work supervisor shall initiate a new Explosives Handlers Training Qualification Record for that worker.

3.22.5 Age Restrictions

No person under 18 years of age shall be permitted to use or handle explosives or engage in any activity relating to blasting operations. No person between 18 and 21 years of age shall be permitted in any explosives magazine or be permitted to use or handle explosives, except under the direct supervision of a qualified explosives handler. No person under 21 years of age shall transport explosives.

4.0 Responsibilities

The responsibilities for individuals and organizations with regard to LLNL explosives operations are described under each title in this section. Overall health and safety responsibilities are specified in Document 2.1, "Laboratory and ES&H Policies, General Worker Responsibilities, and Integrated Safety Management," in the *ES&H Manual.*

4.1 Work Supervisors and Responsible Individuals

Work supervisors and Responsible Individuals are the individuals having direct responsibility for either of the following:

- The safety of the explosives activity or operation.
- The condition of a facility or operation within a facility.

Work supervisors and Responsible Individuals:

- Shall ensure that all explosives operations performed by personnel for whom they are responsible comply with the requirements in this document and those in the *DOE Explosives Safety Manual.*
- Are responsible for providing OJT and ensuring that personnel reporting to them possess the knowledge and skills to perform the work safely.

The organization responsible for the work shall write, obtain review and approval of, and distribute safety plans that incorporate these requirements.

4.2 Payroll Supervisors

Payroll supervisors are responsible for:

- Assigning trained and qualified personnel to perform the functions described in this document.
- Arranging and obtaining medical clearances for explosives handlers before allowing them to routinely handle explosives.

Payroll supervisors of explosives material custodians shall review the annual report of the Site 300 CMG explosives inventory and shall either justify continued storage or arrange for alternate disposition of their explosives.

4.3 Qualified Explosives Handlers

Qualified explosives handlers are responsible for conducting their work:

- In accordance with the requirements in this document and applicable plans and procedures developed within their directorate.
- Within the limitations established as described on each worker's Explosives Handlers Training Qualification Record.

4.4 Facility Point of Contact

The facility point of contact (FPOC) is responsible for ensuring the notification of the emergency dispatcher at Fire Station I (for the LLNL Livermore site facilities) or Fire Station II (for Site 300 facilities) whenever any safety plan for explosives operations changes the status of an Emergency Response Plan (e.g., changing the fire symbol).

4.5 ES&H Team

ES&H Team explosives safety engineers, working through the ES&H Teams, are responsible for:

- Providing guidance to the programs regarding implementation of applicable codes, standards, and regulations.
- Serving on the Laboratory's Explosives Safety Committee.
- Developing and promulgating the LLNL explosives safety controls and standards for approval by management.
- Providing hazards analysis and safety guidance to LLNL staff members who work with explosives.
- Preparing and conducting explosives safety training and maintaining copies of qualification records of explosives handlers.
- Assessing and auditing (upon request) the operations, facilities, and equipment that are part of the LLNL explosives program and making appropriate reports to management.
- Analyzing accidents and incidents related to explosives operations and making recommendations to prevent recurrences.
- Compiling and distributing explosives safety information to personnel working with explosives and other personnel requiring this information.
- Providing planning for (and information during) emergency responses involving explosives.
- Assigning new explosives and explosive devices to the appropriate storage compatibility groups.

4.6 Hazards Control Explosives Safety Subject Matter Expert

- Serving as the Laboratory's authority having jurisdiction for institutional explosives safety-related issues.

- Serving as the Laboratory's primary representative on the DOE Explosives Safety Committee. (Individuals are appointed by the Hazards Control Department head.)
- Serving as the focal point for interpreting, evaluating the impact of, commenting on, and disseminating explosives safety-related rules and regulations promulgated by DOE and other agencies.
- Reviewing and approving purchase order requests for explosive materials and explosive devices.
- Reviewing requests for DOE interim hazard classifications for new explosive materials and articles and exemptions to DOT explosives transportation requirements.
- Ensuring that a central file of all active waivers to the *DOE Explosives Safety Manual* is maintained and ensuring that copies of each approved waiver is provided to the Oakland office of the National Nuclear Security Administration (NNSA-OAK), a primary member of the DOE Explosives Safety Committee.

4.7 Procurement & Materiel Department

When explosive materials or explosives devices are ordered through the Procurement & Materiel Department, the respective procurement specialist shall follow all applicable procurement procedures and supplemental instructions when placing purchase requisitions for explosives and mock explosives. The responsible procurement specialist ensures that such materials and items are designated for delivery to facilities approved for their storage and use.

Site 300 Material Distribution Division personnel are responsible for transporting explosives in a manner that complies with DOT, DOE, and LLNL standards.

4.8 Materials Management Section

The Site 300 CMG of the Materials Management Section is responsible for:

- Shipping, receiving, storing, and transporting explosives. Shipping responsibilities include packaging, marking, and labeling explosives shipments leaving Site 300 and the LLNL Livermore site in a manner that complies with DOT, DOE, and LLNL standards.
- Distributing an annual inventory report of explosives stored under its control to managers, who shall justify continued long-term explosives storage and update consignor lists (see Section 4.2).

4.9 Chemistry and Materials Science Energetic Materials Program Element Leader

The EMPE leader is responsible for:

- Maintaining a competent staff capable of performing peer reviews of explosives operations, applicable chemical compatibility testing, and furnishing technical assistance needed to ensure the compatibility of the materials involved.
- Overseeing the actions of the LLNL Explosives Safety Committee and appointing the chairperson of the committee.

The EMPE staff members are responsible for:

- Reviewing new explosives materials for assignment to the appropriate hazard classification.
- Assigning processing and stability review intervals in accordance with the guidelines in Document 17.2.

4.10 LLNL Explosives Safety Committee

The Explosives Safety Committee serves as an approving authority for each phase of an explosives development program thereby satisfying the requirement for such a committee, as set forth by the *DOE Explosives Safety Manual.* The committee includes various review groups and subcommittees, such as the Peer Review Group, the High Explosives Instrument Committee, and the Low Energy Initiator Committee. Specific responsibilities follow:

- Reviews operating procedures for experiments involving explosives and new explosives operations and equipment upon request.
- Advises the ES&H Working Group, EMPE leader, and facility managers on recommended safety practices.
- Reviews and approves onsite requests for explosive classification.
- Reviews proposed changes to the *ES&H Manual* and the *DOE Explosives Safety Manual.*

4.11 Environmental Protection Department

The Environmental Protection Department performs the following with regards to explosives and explosives waste:

- Oversees the collection, treatment (if applicable), and disposal of regulated wastes.

- Develops and implements hazardous waste-handling procedures, operations, and reporting systems.
- Collects, treats, and stores wastes before shipping to offsite recyclers and treatment and disposal facilities, as applicable.
- Tracks and documents the movement of hazardous waste from waste accumulation areas to final treatment, storage, or disposal areas.
- Responds to environmental emergencies.
- Participates in spill cleanup.

4.12 Health Services Department

The Health Services Department is responsible for establishing a medical surveillance program and monitoring LLNL employees who handle bare explosive materials. The Health Services Department can answer questions employees may have regarding potential health effects of explosives handling and the need for medical surveillance.

4.13 Mechanical Engineering Department

The Mechanical Engineering Department is responsible for ensuring that designs, fabrications, assemblies, mockups, and other equipment and materials associated with the LLNL Explosives Program are properly reviewed and meet the requirements in the *ES&H Manual.*

5.0 Work Standards

5.1 Work Smart Standards

DOE Order 440.1A, "Worker Protection Management for DOE Federal and Contractor Employees," Attachment 2, "Contractor Requirement Document," Sections 1–11, 13–18 (delete item 18.a), 19 (delete item 19.d.3) and 22.

DOE M 440.1-1, *DOE Explosives Safety Manual*, LLNL Work Smart Standards Version.

http://www.explorer.doe.gov:1776/pdfs/doe/doetext/neword/440/m4401-1.html

29 CFR 1910.119, "Process Safety Management of Highly Hazardous Chemicals."

DOE-STD-1090-99, "Hoisting and Rigging Standard."

NFPA 496, "Purged and Pressurized Enclosures for Electrical Equipment."

5.2 Other Requirements

DOD 6055.9-STD, "Ammunition and Explosives Safety Standards."

Document 41.1, "LLNL Quality Assurance Program," in the *ES&H Manual.*

6.0 Resources for More Information

6.1 Contacts

Contact the following, as appropriate, for further guidance or additional information:

- ES&H Team.
- Hazards Control explosives safety SME.
- Site 300 CMG.
- Chemistry & Materials Science Energetic Materials Program Element leader.

6.2 Applicable Lessons Learned

Refer to the list of Lessons Learned at the following Internet address:

http://www-r.llnl.gov/es_and_h/lessons/lessons.shtml

6.3 Other Sources

Cady, W. E. (1978-1981) *Development of Alternate Silicone Potting Compounds*, Vols. 1–9, Lawrence Livermore National Laboratory, Livermore, California, UCRL-52434.

DoD *Ammunition and Explosives Hazard Classification Procedures* (TB 700-2).

DoD 6055.9-STD, "DOD Ammunition and Explosives Safety Standards."

http://web7.whs.osd.mil/html/60559std.htm

Kelley, R. and G. Miller, *Standard for Storing and Using Peroxidizable Organic Chemicals*, Lawrence Livermore National Laboratory, Livermore, California (UCRL-AR-133218).

Miles, J. B. (1998), Memorandum regarding "Process Safety Management Interpretation," dated February 4, 1998, U.S. Department of Labor.

Development of Halthane Adhesives for Phase 3 Weapons: Summary Report, Lawrence Livermore National Laboratory, Livermore, California, December 5, 1980 (UCRL-52943).

LLNL Explosives Handbook: Properties of Chemical Explosives and Explosive Simulants, Lawrence Livermore National Laboratory, Livermore, California (UCRL-52997).

Appendix A

Guide to Preparing Waivers

This appendix describes the individuals responsible for preparing, reviewing, and approving waivers for operations, areas, and buildings that are not in compliance with advisory requirements given in the *DOE Explosives Safety Manual* but that are determined to be safe and necessary. It also includes an example of the format and content of waivers, as well as guidance for providing the necessary information enclosed in brackets ([...]).

A.1 Waiver Preparation

The person having direct responsibility for a noncompliant operation, area, or building is responsible for the preparation, review, and approval of the waiver. ES&H Team explosives safety engineers can assist in this process and should be involved as early as possible to help identify all explosives safety concerns that may be present.

As a minimum, all waivers shall contain the information listed below. The example at the end of this appendix provides detailed guidance about preparing waivers.

- The operation, area, or building involved.
- Specific standard requiring the waiver.
- A description of the condition or activity that is not in compliance.
- Safety measures in place or proposed to provide alternate protection.
- A risk assessment.
- Waiver duration or expiration date.

All new and existing waivers shall be in effect for a maximum of 3 years. Activities whose waivers have expired shall be terminated until a new waiver is reviewed, approved, and reissued with a new expiration date and identification number.

A.2 Review and Approval of Waivers

A.2.1 Review

All waivers shall be thoroughly reviewed by the appropriate levels of management to ensure that the content reflects current activities and complies with ES&H regulations. The following individuals typically review, concur with, and approve waivers (they

may delegate the authority for these tasks to others but still retain full responsibility for the validity, effectiveness, and timeliness of the review process):

Reviewers

- Responsible supervisors.
- ES&H Team leader.
- ES&H Team explosives safety engineer (who is required to ensure that proper paragraphs are cited, the waiver is in the proper format, and the risk assessment is adequate).

Concurrence

- Facility manager (for operations conducted in his/her facility).
- Facility AD or designee (if the activity is conducted under the programmatic management or another AD).
- Site 300 manager (only for activities conducted at Site 300).

A.2.2 Approval

All waivers shall be approved by the program AD (or designee) for programmatic work or by the facility AD (or designee) for facility operations. If approval authority is delegated to someone else, a letter is required from the AD and shall be on file with the Hazards Control Department explosives safety SME. An approval signature on the completed waiver indicates that the activity or condition is warranted and that the residual risk associated with the noncompliance is accepted by line management.

A.3 Waiver Dissemination

The Hazards Control explosives safety SME is responsible for the following:

- Disseminating copies of the approved waiver to each waiver signatory and the DOE-OAK primary member of the DOE Explosives Safety Committee.
- Maintaining a central file of all active waivers.

Example of Waiver for Explosive Operations

LLNL Waiver No.: [Provided by Hazards Control Explosives Safety (99-02)]

Issued: [Expected date waiver will be signed by approving authority (4/15/99)]

Expires: [No more than 3 years minus one day from the expected signing day (4/14/02)]

1. **Operation, Area, or Building Involved.** [Give the building number, room number when applicable, and the operations to be performed. Do not group buildings. A separate waiver is required for each separate building if the activity or condition is not sitewide.]

2. **Responsible Individual or Supervisor.** [Give the name of the individual who has direct supervisory responsibility for the operation being waived.]

3. **Specific Standard Requiring Waiver.** [Cite the chapter and paragraph number from DOE M-440.1-1. In addition, quote the requirement that requires deviation.]

4. **Description of the Condition or Activity Not in Compliance.** [Describe the condition or activity that does not comply with the requirements cited in step 3 above (e.g., access doors are not interlocked to the remote operating equipment). Give specific details and not generalities. Include maps and attachments where applicable to clarify deviations. For example, attach maps showing power pole and facility locations, length of power lines, and distances to explosives facilities.]

5. **Safety Measures in Place or Proposed to Provide Alternate Protection.** [Gives actions taken and safety controls provided to achieve equivalent protection that precludes or reduces the severity of an accident resulting from noncompliance with the standard. (For example, doors can be locked with a padlock during remote operations and the keys kept under the control of the supervisor instead of interlocking access doors to remote equipment.)]

6. **Justification for Condition or Activity that Is Not in Compliance.** [This is the management justification explaining why the condition or activity is not in compliance with DOE M-440.1-1 guidance. Be specific. Normally, physical or operational requirements that preclude compliance are given here. If it is not practical or cost effective to bring the activity into compliance, state why. If corrective actions are proposed, include the schedule for completion.]

7. **Risk Assessment.** [Provide a brief, subjective risk assessment describing the maximum credible event that could occur by not following the guidance in DOE M-440.1-1. This should include potential consequence(s), including maximum quantities of explosives that could be initiated, risk to personnel, and risk to equipment and facilities.]

8. **Other Comments.** [Indicate which waiver the new waiver replaces, if applicable. Use this area to provide other comments that might be relative to the waiver. If there are no comments, enter the word "None."]

REVIEWED BY

Responsible Individual or Work Supervisor [This should be the individual having direct responsibility for the condition or operation that requires the waiver.]

Explosives Safety Engineer [This should be the ES&H Team explosives safety engineer with oversight responsibility for the operation.]

ES&H Team Leader [This should be the ES&H Team leader with oversight responsibility for the operation.]

CONCURRENCE BY:

Facility Manager [This should be the individual responsible for the facility's FSP and safety analysis report (SAR).

Site 300 Manager [Required for all Site 300 waivers because of the interrelationship with Site 300 facilities and operations, as well as their potential impact on one another.]

Facility Associate Director [This is the AD responsible for the facility and the program unless the activity is conducted under the programmatic management of another AD. Lower levels of approval authority are authorized only when the cognizant AD has delegated such authority in writing. A copy of such delegation shall be on file with the Hazards Control explosives safety representative.]

APPROVED BY

Program Associate Director [This is the AD responsible for the program if the activity is conducted under the facility management of another AD. Lower levels of approval authority are authorized only when the cognizant AD has delegated such authority in writing. A copy of such delegation shall be on file with the Hazards Control explosives safety representative. The signature block is deleted when the facility AD and programmatic AD are the same.]

cc: Explosives safety subject matter expert (original)
Each signatory
DOE-OAK Explosives Safety Committee Member

Appendix B

Explosives Storage Compatibility Control Category

B.1 Explosives

LLNL uses the UNO hazard classification system for classifying explosive materials and explosive components. Each SCG is described in Section 2.2 of this document. Contact Hazards Control explosives safety personnel to resolve questions concerning classification conversion from the previous handling classification type to the new UNO hazard classification system.

Table B.1 Explosives listed by UNO storage compatibility group.

Group A—Initiating explosives (* indicates primary initiating explosives)
CL-20 (Hexanitrohexaazaisowurtzitane; dry)
CP (5-Cyanotetrazolpentaamine Cobalt III perchlorate)
HMX (Cyclotetramethylene tetranitramine; dry)
*Lead azide
*Lead styphnate
*Mercury fulminate
*Nitrocellulose (dry)
PETN (Pentaerythritol tetranitrate; dry)
RDX (Cyclotrimethylene trinitramine; dry)
*TATNB (Triazidotrinitrobenzene)
*Tetracene
Group B—Detonators and similar initiating devices
Blasting caps
Detonators (excluding EBW and slapper)
Explosive bolts
Fragmenting actuators
Ignitors
Low-energy initiators (LEIs)
MDF (mild detonating fuze) detonator assemblies
Pressure cartridges
Primers
Squibs

Group C—Bulk propellant, propellant charges, and devices containing propellants with or without their own means of initiation
Smokeless powder
Pistol and rifle powder
Rocket-motor solid propellants
Group D—High explosives and devices containing explosives without their own means of initiation (* indicates that classification may change depending on nitrogen and moisture content. Contact Hazards Control explosives safety personnel for additional guidance.)
Ammonium picrate
Baratol
Black Powder
Boracitol
Chemical lenses
CL-20 (Hexanitrohexaazaisowurtzitane; wet)
Compositions A, B, and C (all types)
Cyclotols (≤ 85% RDX)
DATB (Diaminotrinitrobenzene)
Detasheet
Detonating cord (primacord or mild detonating fuze)
bis-Dinitropropyl adipate
bis-Dinitropropyl glutarate
bis-Dinitropropyl maleate
Dinitropropane
Dinitropropanol
Dinitropropyl acrylate monomer (DNPA)
Dinitroproply acrylate polymer (PDNPA)
EBW and slapper detonators
Elastomeric plastic bonded explosives
Explosive D
GAP (Glyceryl azide polymer)
HMX (Cyclotetramethylene tetranitramine; wet)
HMX / wax (formulated with at least 1% wax)
HNS (Hexanitrostilbene; wet or dry)
Linear-shaped charge
Methyl dinitropentanoate
Mild detonating fuze (MDF)
NG / TA (Nitroglycerine-triacetine)
*Nitrocellulose (wet)

Group D—(cont.)
Nitroguanidine (NQ)
Octol (≤ 75% HMX)
Pentolite
PETN (Pentaerythritol tetranitrate; wet)
PETN / extrudable binder
PGN (Polyglycidyl nitrate)
Plane wave lenses (composed of SC / HC Group D explosives)
Plastic-bonded explosive, PBX (a SC / HC Group D formulated with a desensitizing binder)
Potassium picrate
Primacord
RDX (Cyclotrimethylene trinitramine; wet)
Shaped charges (composed of SC / HC Group D explosives)
TATB (Triamino trinitrobenzene)
TATB / DATB mixtures
TEGDN (Triethylene glycol dinitrate)
Tetryl
TMETN (Trimethylolethane trinitrate)
TNAZ (Trinitoazetidine)
TNT (Trinitrotoluene)
Group E—Explosives devices without their own means of initiation and with propelling charge
Artillery ammunition
Rockets (e.g., M66 LAW)
Group F—Explosives devices with detonators and detonating trains assembled to the devices and with propelling charge
Grenades
Sounding devices
Group G—Pyrotechnic material and devices that produce an incendiary, illumination, lachrymatory, smoke, or sound effect
Smoke pots / grenades
Flares
Incendiary ammunition
Group H—Ammunition containing both explosives and white phosphorus (WP) or other pyrophoric material
White phosphorus
Plasticized white phosphorus

Group J—Ammunition containing both explosives and flammable liquids or gels
Liquid- or gel-filled incendiary ammunition
Fuel–air explosive (FAE) devices
Flammable liquid-fueled missiles
Torpedoes
Group K—Ammunition containing both explosives and toxic chemicals
Artillery or mortar ammunition (fuzed or unfuzed), grenades, rockets, or bombs filled with a lethal or incapacitating agent
Group L—Explosives or other ammunition not included in other storage compatibility groups
Damaged or suspect explosives devices or containers
Explosives that have undergone severe testing
Experimental explosives, explosives of temporary interest, newly synthesized compounds, new mixtures, and some salvaged explosives
Group N—Hazard Class/Division 1.6 ammunition containing only extremely insensitive detonating substances (EIDS)
Bombs
Warheads
Group S—Explosives, explosives devices, or ammunition presenting no significant hazard
Propellant cartridge-actuated devices (which yield a nonfragmenting, non-flame-producing, controlled reaction). Examples include cable cutters, cartridge-actuated valves, and linear actuators (e.g., dimple, piston, or bellows motors)
Safety fuse
Most small arms ammunition below 50 caliber
Thermal batteries

B.3 Other Energetic Materials

The energetic materials listed below are materials and systems that do not need to be stored or labeled as explosives unless they are near other explosives that could initiate them. When near explosives, these materials become SCG D unless otherwise indicated.

- Explosive, SCG A (nonprimary initiating explosives only) and SCGs C and D, ≤ 10 mg.
- Explosive, SCG A primary initiating explosives, ≤ 1 mg.
- FEFO / SOL (35 wt% or less FEFO in ethyl acetate or 25 wt% or less FEFO in methylene chloride) FM1 solution.

- SCG D explosives in inert solvents (explosives concentration not exceeding 25 wt%). Explosives in inert solvents shall only be handled in authorized explosive work areas. Exceptions may be made for specific explosive–solvent combinations; this requires a peer review that demonstrates the nonexplosive nature of the combination of ingredients. For such a peer review, a signature by the Explosives Safety Committee chair or Energetic Materials Program Element leader is required in addition to the standard three signatures required for all peer reviews.
- Nitrates (treat as SCG C when with other explosives).
- Nitromethane (unsensitized).
- Nitropropane.
- Perchlorates (treat as SCG C when with other explosives).
- Picric acid (containing at least 10 wt% water and in less than 11-kg lots).
- Small arms ammunition classified for shipment as ORM-D (Other Regulated Material Class D) rather than Hazard Class / Division 1.4S explosives. Normally consists of ammunition not exceeding 50 caliber for handguns and rifles and 8 gauge for shotguns.

Appendix C

Hazard Classification of Explosives

C.1 Introduction

Initially, newly synthesized compounds, new mixtures and explosive material, and new explosives devices are automatically assigned to the Hazard Class / Division 1.1 and SCG L classification (unless there is sufficient information on sensitivity, stability, and handling history for assignment to another SCG). Before this classification can be changed, information from various tests performed on the explosive or other pertinent safety data shall be reviewed and approved by the LLNL Explosives Safety Committee (for explosive materials) or ES&H Team explosives safety engineers (for explosives devices).

C.2 Classification of Explosive Materials

New explosive materials are all initially classified as SCG L with a machining classification of Remote. To initiate the classification process, the experimenter or requester shall submit a completed Explosives Safety Data form (Appendix D; also available from the EMPE staff) to the EMPE leader. After EMPE peer review and concurrence with this report, Hazards Control explosives safety personnel publish the new classification in the appropriate listings, manuals, and procedures.

C.2.1 Required Tests

The following tests are required for explosives to be classified:

- Impact sensitivity.
- Spark sensitivity.
- Differential thermal analysis (DTA) or differential scanning calorimetry (DSC).

C.2.2 Additional Recommended Tests

The following additional tests may be recommended at the discretion of the EMPE leader or ES&H Team explosives safety engineers:

- Friction sensitivity—small-scale test.

- Shock sensitivity—gap test.
- LLNL chemical reactivity test (CRT).
- One-dimensional time-to-explosion (ODTX).

C.3 Classification of Explosive Devices

Explosives devices are manufactured components containing explosives; all are initially classified as SCG L. ES&H Team explosives safety engineers review available information and reclassify those devices that clearly meet the criteria for other SCGs. Explosive detonators and similar initiating devices with questionable characteristics are referred to the LEI Committee for resolution. For additional information on the functions of the LEI Committee, see Document 17.3.

C.4 Classification Change to Contact Machining

Explosives are all initially classified as remote machinable. To classify an explosive as contact machinable, a peer review of the procedure that describes and initiates a machining overtest program for the explosives is conducted. A final report of the machining overtest program and the results of the required tests (listed below) is prepared. After satisfactory completion of the machining overtests, and with the concurrence of those involved, the Hazards Control explosives safety SME forwards a request to the chairperson of the DOE Explosives Safety Committee to add the explosive to the list of contact-machinable explosives contained in the *DOE Explosives Safety Manual*. After approval by the DOE Explosives Safety Committee, Hazards Control explosives safety personnel arrange for dissemination of the information.

C.4.1 Required Tests

The following tests are required to classify explosives for contact machining:

- All of the tests required to classify explosives to SCG D.
- Sliding impact sensitivity—LLNL / Pantex skid test.
- Machining overtest program, which involves sawing, machining, and drilling without coolant and is designed to exceed the speed and feed parameters normally used.

Appendix D

Explosives Safety Data Form

Part I. General Information

Owner_____ **Explosive ID and LLNL Lot No.**_____
Manufacturer_____
Manufacturer's designation_____
UNO hazard class/division_____ **SC/HC group**_____
DOT reference number_____
IHC (if applicable) and expiration date_____
Composition or chemical name_____
Date manufactured_____ **Date received by LLNL**_____
Explosive components and their processing and/or stability review dates_____
Manufacturer's recommended shelf life_____
Physical state (solid/liquid, melting point, or boiling point)_____
Color_____

Part II. Stability Information

Stabilizer_____ **Original manufactured stabilizer wt%**_____
% Effective stabilizer_____
ASSIGNED STABILITY REVIEW INTERVAL_____
ASSIGNED STABILITY REVIEW DATE_____

Part III. Sensitivity Information

Sensitivity: **DSC or DTA exotherms (attach curves)**
Chemical Reactivity Test (CRT)_____**cm^3/g at**_____**°C for** _____**h**
Impact 2.5 kg **Type 12** **Type 12B**
Sample_____
Control_____
Spark_____
Friction_____
One-Dimensional Time to Explosion (ODTX)_____
Other_____
Precautions: **Toxicity**_____
Compatibility_____
Protective equipment_____
Other_____
ASSIGNED PROCESSING REVIEW INTERVAL_____
ASSIGNED PROCESSING REVIEW DATE_____

Explosives Safety Committee Peer Review **Concurrence:**_____
Group I_____ **Hazards Control Explosives Safety**
Group II_____
Group III_____ **Approval:**_____
Explosives Safety Committee Chair

Distribute copies to: Owner/Consignor, Hazards Control Explosives Safety, and Site 300 Controlled Materials Group. Original to be retained by Energetic Materials Program Element master file.

Appendix E

Adhesives, Tapes, Fillers, Coatings and Crack-Detecting Fluids Approved for Use with Explosives

E.1 Introduction

The adhesives, tapes, fillers, coatings, and crack-detecting fluids described in this appendix have been reviewed and are approved for use with explosives as described. The main hazards associated with such materials are their possible chemical incompatibility with the explosives, their exothermic reaction during cure, and their toxicity.

Controls for some specific adhesives, tapes, fillers, coatings, and crack-detecting fluids are listed below. Section 5.3 of the *LLNL Explosives Handbook*, "Properties of Chemical Explosives and Explosive Simulants," provides additional information concerning the compatibility of materials with explosives. For information about materials not discussed in this appendix, contact the LLNL EMPE leader or the LLNL Explosives Safety Committee chair, who furnishes the technical assistance needed to ensure the compatibility of the materials involved. In general, all new materials coming into direct contact with explosive materials not listed require differential scanning calorimetry (DSC), the chemical reactivity test (CRT), and cure inhibition testing.

Adequate facilities (e.g., fume hood and eyewash stations), equipment, and personal protective equipment (e.g., gloves, goggles, and safety glasses) necessary to control the hazards related to specific chemical operations shall be obtained before beginning work. Use local-exhaust ventilation fume hoods or close-capture systems for operations that produces gas, vapor, or airborne particulates in the work environment. The ES&H Team should be contacted when questions arise concerning the determination of appropriate protective equipment and ventilation controls.

E.2 Adhesives

Only reviewed and approved adhesives are authorized for use in direct contact with explosives that have been specifically evaluated. Explosives that have been evaluated and were found acceptable include all TATB-, TNT-, RDX-, HMX-, and PETN-based formulations. All adhesives to be used with an explosive that is not listed shall be individually reviewed and approved. Compatibility test results shall be used cautiously because the manufacturers of adhesives may improve the material without notice. Manufacturing changes in the composition of an adhesive can make the material incompatible with explosives. Therefore, any change in formulation shall be considered a new material.

Adhesives may need to be applied in thin films if the cure reaction of the paste adhesives is exothermic and may produce excess heat in thicker sections. The manufacturer's recommended procedure for mixing and handling an adhesive should always be followed. Table E-1 provides information on the adhesives approved for use with various explosives.

E.2.1 Adiprene LW-520

Adiprene LW urethane prepolymers, as uncured liquid, contains methylene-bis [4-cyclohexyl diisocyanate] (H_{12}MDI), which is a strong skin sensitizer and causes severe irritation to eyes, skin, and mucous membranes. Adiprene LW-520 is Adiprene LW that has been cured with methylenedianiline (MDA), a potent liver carcinogen to which OSHA substance-specific standards apply.

Handling Precautions. MDA shall be handled according to the requirements and guidelines set forth in Document 14.12, "Safe Handling of Carcinogenic Materials," in the *ES&H Manual.* The explosives handler shall also take special care to avoid breathing the MDA dust: use of a filter-type respirator is recommended. DuPont Co. also suggests the following safety precautions:

- Avoid overheating the MDA.
- Provide a failsafe mechanism for the MDA temperature control that, in the event of an irregularity, will turn off the heating system.
- Provide a pressure-relief system for the MDA vessel to permit pressure dissipation in case of thermal breakdown. This relief system should be oriented so that the venting stream of gases and hot MDA are directed away from any personnel area and, preferably, into an outside exhaust system.
- Have the operators observe the temperature of the MDA system regularly as an added precaution.

E.2.2 Other Urethane Adhesives

Table E-1 also shows other urethane adhesives (Halthanes and L-315/Polyol). These adhesives should be handled and stored in a manner similar to that used for LW-520/MDA. The manufacturer's data sheets should be available, and any precautionary controls should be followed. If data sheets for these adhesives are not available, the material safety data sheets for isocyanates and precursors should be considered. The explosives handler should take care to avoid skin contact with and inhalation or ingestion of these adhesives. Any question about urethane adhesives should be directed to the area ES&H Team.

Table E-1. Adhesives approved for use with specified explosives.[a]

Adhesives	High explosives							
	Baratol	Comp B	Detasheet	LX-04	LX-07	LX-10	LX-14	LX-17
Adiprene LW-520/HGH 99	A	A	—	A	A	A	A	A
Adiprene L315	A	A	—	A	A	A	A	A
Cyanoacrylate (generic)	A	A	A	A	A	A	A	A
Epoxies[b]	—	—	—	—	—	—	—	—
Explostix 473[c]	—	—	—	—	—	—	—	A
Halthane 73-14[d]	A	A	—	A	A	A	A	A
Halthane 73-15[d]	A	A	—	A	A	A	A	A
Halthane 73-18[d]	A	A	—	A	A	A	A	A
Halthane 73-19[d]	A	A	—	A	A	A	A	A
Halthane 87-1[d]	A	A	—	A	A	A	A	A
Halthane 87-2[d]	A	A	—	A	A	A	A	A
Laminac 4116	—	—	A	A	A	A	—	—
Dexter Epoxy #615								A
3M #465	—	—	—	A	A	A	—	—
3M #466	—	—	—	A	A	A	—	—
3M #Y9146	—	—	—	A	A	A	—	—

Adhesives	High Explosives						
	PBX-9007	PBX-9010	PBX-9205	PBX-9404	PBX-9407	Tetryl	TNT
Adiprene LW-520/MDA	—	A	A	A	—	A	A
Adiprene L315/Polyol	—	A	A	A	—	A	A
Aerobond 2017	—	—	—	A	—	—	—
Cyanoacrylate	—	A	A	A	—	A	A
Epoxies[b]	—	—	—	—	—	—	—
Explostix 473[c]	—	—	—	—	—	—	—
Halthane 73-14[d]	—	A	A	A	—	A	A
Halthane 73-15[d]	—	A	A	A	—	A	A
Halthane 73-18[d]	—	A	A	A	—	A	A
Halthane 73-19[d]	—	A	A	A	—	A	A
Halthane 87-1[d]	—	A	A	A	—	A	A
Halthane 87-2[d]	—	A	A	A	—	A	A
Dexter Epoxy #615							
Laminac 4116	—	—	—	A	—	—	—
3M #465	A	—	—	—	A	—	—
3M #466	A	—	—	—	A	—	—
3M #Y9146	A	—	—	—	A	—	—

[a] Compatible, acceptable for long-term storage (A); compatibility has not been checked (—).

[b] BIPAX-2902, EPY-150, and HYSOL epoxy patch kits are epoxies certified only for short-term bonding of strain gauges to LX-04, LX-07, LX-10, LX-17, and PBX-0404.

[c] Explostix 473 is approved for TATB/LX-17 and PBX-9502.

[d] Compositions, mixing ratios, and characterization of the Halthane adhesives are given in UCRL-52943 (1980).

E.2.3 Cyanoacrylate Adhesives

Cyanoacrylate is a monomer that has been modified with a thickening agent and plasticizer to produce rapid and strong bonds between a large number of materials. Heat, excessive pressure, and catalysts are usually unnecessary when this adhesive is used. The chemical change that occurs when a film of cyanoacrylate is pressed between the surfaces of two potential adherents results in a strong bond.

Do not use a cyanoacrylate adhesive joint as the sole support for holding an explosives charge if the bonded joint is under shear or tension. Despite this restriction, cyanoacrylate adhesive is used quite extensively in the trim and assembly of various explosives components.

Do not use a cyanoacrylate adhesive on uncased detonators or tetryl pellets, because it acts as a solvent and will distort the dimensions of the detonators.

E.2.4 Epoxy Resins

Uncured (i.e., liquid) aliphatic-amine epoxy-resin systems are not compatible with most explosives and propellants. However, aliphatic- and aromatic-amine epoxy resins are considered compatible when fully cured (e.g., epoxy laminates). Three epoxies have been certified for bonding strain gauges to LX-04, LX-07, LX-09, LX-10, and PBX 9404: BIPAX-2902, EPY-150, and HYSOL Epoxy Patch Kit #615. Two other epoxy resin adhesives, RESIBOND #907A and #907B, have been approved for use with PBX-9404 and TATB. Explostix 473 was specifically designed for bonding of LX-17 explosives.

E.3 Tapes

Only reviewed and approved tapes are authorized for use in direct contact with explosives that have been specifically evaluated. Explosives that have been evaluated and were found acceptable include all TATB-, TNT-, RDX-, HMX-, and PETN-based formulations. All new formulations with an explosive not listed shall be individually reviewed and approved. Approved tapes authorized for specific explosives identified are listed in Table E-2.

Table E-2. Tapes approved for use with specified explosives.

Manufacturer	Trade name	Number	Color
3M	Scotch Electrical (vinyl)	33	black
3M	Scotch Mylar	56	yellow
3M	Scotch Electrical	57	yellow
3M	Scotch Masking (paper)	232	tan
3M	Scotch Photo	235	black
3M	Scotch Double-Sided Masking	400	tan
3M	Scotch Metallic Lead	420	lead-gray
3M	Scotch Double-Sided Masking	465 & 466	tan
3M	Scotch Plastic	471	yellow, red, white
3M	Scotch Cellophane	600 & 850	clear
3M	Scotch Magic-Mending	810	clear
3M	Scotch Filament	880	pearl
3M	Scotch Double-Sided Masking	Y9146	tan
Behr-Manning	Bear Tape	4/1	tan
Hampton Manufacturing	Blue Cross	none	yellow
Mystic Tape	Mystic	5803	black
Okonite	High-Voltage Rubber Tape	none	brown
Permacel	Permacel	29	black
Permacel	Permacel	32	red
Permacel	Permacel Cellophane	none	clear
Saunders Engineering	Teflon	S15 (2 mils)	blue/brown
Saunders Engineering	Teflon	S16 (5 mils)	blue/brown
Saunders Engineering	Teflon	S19 (10 mils)	blue/brown
Technical Tape	Tuck Tape	none	yellow, black
Nashua	Nashua	none	black

E.4 Fillers and Coatings

Only reviewed and approved fillers and coatings are authorized for use in direct contact with explosives that have been specifically evaluated. Explosives that have been evaluated and were found acceptable include all TATB-, TNT-, RDX-, HMX-, and PETN-based formulations. All new formulations with an explosive not listed shall be individually reviewed and approved. The fillers and coatings approved for use with specified explosives are listed in Table E-3.

Table E-3. Silicone potting compounds approved for use with specified explosives.[a]

Silicone potting compounds	High explosives							
	LX-04	LX-07	LX-10	LX-14	LX-17	PBX-9010	PBX-9205	PBX-9404
APC 1[b,c]	A	A	A	A	A	A	A	A
APC 2.5[b,c]	A	A	A	A	A	A	A	A
APC 5[b,c]	A	A	A	A	A	A	A	A
APC 10[c]	A	A	A	A	A	A	A	A
APC 300[b,c]	A	A	A	A	A	A	A	A
GE RTV 632[b,d,e]	A	A	A	A	A	A	A	A
Silastic RTV 732[d]	A	A	A	A	A	A	A	A
Silastic RTV 891[d]	A	A	A	A	A	A	A	A
Sylgard 182[f]	A	A	A	A	A	A	A	A
Sylgard 184[f]	A	A	A	A	A	A	A	A
Sylgard 186[f]	A	A	A	A	A	A	A	A
DP 4817[g]	A	A	A	—	A	B	—	A

[a] Compatible, acceptable for long-term storage (A); compatible, acceptable for short-term storage (B); compatibility has not been checked (—).

[b] These materials are under the influence of a platinum catalyst. They are easily poisoned by a number of materials and should therefore be mixed only in clean containers.

[c] The addition potting compound (APC) formulations were developed at LLNL and at Pantex (see *Development of Alternate Silicone Potting Compounds*).

[d] Room temperature vulcanizing (RTV); the APCs are also RTVs.

[e] This formulation of a nonflowing material can be used where a material of very high viscosity is needed.

[f] Manufactured by Dow Chemical Co.

[g] Electrically conductive silver paint manufactured by E. I. DuPont de Nemours and Co., Inc.

See Table E-4 for the properties of some fillers and coating materials. In addition, aluminum silicofluoride in a water and polyvinyl alcohol slurry can safely be used as a flasher coating on most SCG D explosives. Although fillers and coatings are in general much less toxic than adhesives, the manufacturer's recommendations for control of skin contact or ventilation should be followed carefully.

Table E-4. Some properties of silicone potting compounds (RTV) used with explosives.

Properties	APC 1[a]	APC 2.5	APC 10	APC 300	Sylgard 184
10-min viscosity at 25°C (Pa-s)	—	2–3	9–10	—	2.5–3.5
Gel time at 25°C, minimum	20 ± 10	90 ± 30	90 ± 30	—	200–800
2-h hardness, Shore A, minimum	—	—	—	7	—
6-h hardness, Shore A, minimum	—	20	20	—	—
24-h hardness, Shore A minimum	20	30	35	35	—

[a] Addition potting compound.

E.5 Crack-Detecting Fluids

Only reviewed and approved crack-detecting fluids are authorized for use in direct contact with explosives that have been specifically evaluated. Explosives that have been evaluated and were found acceptable include all TATB-, TNT-, RDX-, HMX-, and PETN-based formulations. All new explosive formulations not listed shall be individually reviewed and approved. Food and Drug Administration (FDA) food colorings Red No. 2 and Green No. 3 are exceptional crack-detecting fluids when mixed in the following proportions:

Crack-detecting Fluids	Weight %	Parts by weight
FDA food coloring (red or green)	**0.13**	**0.08**
Ethyl alcohol	**26.01**	**16.50**
Tap water	**73.15**	**46.4**
Aerosol wetting agent	**0.71**	**0.45**